Claims

We claim:

1. An acoustically-coupled transformer, comprising:
a stacked bulk acoustic resonator (SBAR), comprising:
a stacked pair of film bulk acoustic resonators (FBARs), each of the FBARs comprising opposed planar electrodes and a layer of piezoelectric material between the electrodes, and
an acoustic decoupler between the FBARs;
first terminals electrically connected to the electrodes of one of the FBARs; and
second terminals electrically connected to the electrodes of the other of the FBARs.

2. The transformer of claim 1, in which the acoustic decoupler comprises a layer of acoustic decoupling material.

3. The transformer of claim 2, in which:
the piezoelectric material has an acoustic impedance; and
the acoustic decoupling material has an acoustic impedance less than the acoustic impedance of the piezoelectric material.

4. The transformer of claim 3, in which the acoustic decoupling material has an acoustic impedance intermediate between the acoustic impedance of the piezoelectric material and the acoustic impedance of air.

5. The transformer of claim 2, in which the acoustic decoupling material has an acoustic impedance in the range from about 2 Mrayl to about 16 Mrayl.

6. The transformer of claim 2, in which the acoustic decoupling material comprises plastic.

7. The transformer of claim 2, in which the acoustic decoupling material comprises polyimide.

8. The transformer of claim 2, in which the acoustic decoupling material comprises poly(para-xylylene).

9. The transformer of claim 2, in which:

the transformer has a pass band characterized by a center frequency; and

the layer of acoustic decoupling material has a nominal thickness equal to an odd integral multiple of one quarter of the wavelength in the acoustic decoupling material of an acoustic wave having a frequency equal to the center frequency.

10. The transformer of claim 1, in which the acoustic decoupler comprises a Bragg structure.

11. The transformer of claim 10, in which the Bragg structure comprises one or more low acoustic impedance Bragg elements interleaved with high acoustic impedance Bragg elements.

12. The transformer of claim 11, in which two of the high acoustic impedance Bragg elements additionally serve as one of the electrodes of each of the FBARs.

13. The transformer of claim 1, in which:

the SBAR is a first SBAR; and

the transformer additionally comprises:

a second SBAR, comprising:

a stacked pair of FBARs, each FBAR comprising opposed planar electrodes and a layer of piezoelectric material between the electrodes; and

an acoustic decoupler between the FBARs,

a first electrical circuit connecting one of the FBARs of the first SBAR to one of the FBARs of the second SBAR and to the first terminals, and

a second electrical circuit connecting the other of the FBARs of the first SBAR to the other of the FBARs of the second SBAR and to the second terminals.

14. The transformer of claim 13, in which the acoustic decoupler of each of the SBARs comprises a layer of acoustic decoupling material.

15. The transformer of claim 14, in which:

the piezoelectric material of each of the SBARs has an acoustic impedance; and

the acoustic decoupling material has an acoustic impedance less than the acoustic impedance of the piezoelectric material.

16. The transformer of claim 14, in which the acoustic decoupling material has an acoustic impedance in the range from about 2 Mrayl to about 16 Mrayl.

17. The transformer of claim 14, in which:

the transformer has a pass band characterized by a center frequency; and

the acoustic decoupling material has a nominal thickness equal to an odd integral multiple of one quarter of the wavelength in the acoustic decoupling material of an acoustic wave having a frequency equal to the center frequency.

18. The transformer of claim 13, in which the acoustic decoupler of each of the SBARs comprises a Bragg stack.

19. The transformer of claim 18, in which the Bragg structure comprises one or more low acoustic impedance Bragg elements interleaved with high acoustic impedance Bragg elements.

20. The transformer of claim 19, in which two of the high acoustic impedance Bragg elements additionally serve as one of the electrodes of each of the FBARs.

21. An acoustically-coupled transformer, comprising:

a first stacked bulk acoustic resonator and a second stacked bulk acoustic resonator (SBAR), each SBAR comprising:

a stacked pair of film bulk acoustic resonators (FBARs), each of the FBARs comprising opposed planar electrodes and a layer of piezoelectric material between the electrodes, and

an acoustic decoupler between the FBARs;

a first electrical circuit connecting one of the FBARs of the first SBAR to one of the FBARs of the second SBAR; and

a second electrical circuit connecting the other of the FBARs of the first SBAR to the other of the FBARs of the second SBAR.

22. The transformer of claim 21, in which:

the first electrical circuit connects the one of the FBARs of the first SBAR in one of (a) series and (b) anti-parallel with the one of the FBARs of the second SBAR; and

the second electrical circuit connects the other of the FBARs of the first SBAR in one of (c) series and (d) anti-parallel with the other of the FBARs of the second SBAR.

23. The transformer of claim 22, in which:

the transformer additionally comprises first terminals and second terminals;

the first electrical circuit additionally connects the ones of the FBARs to the first terminals; and

the second electrical circuit additionally connects the others of the FBARs to the second terminals.

24. The transformer of claim 23, in which the first terminals constitute primary terminals and the second terminals constitute secondary terminals.

25. The transformer of claim 22, in which:

the transformer additionally comprises a substrate arranged support the SBARs;

in the one of the FBARs of each the SBARs, one of the electrodes thereof is a first electrode, the other of the electrodes thereof is a second electrode, and the first electrode is closer to the substrate than the second electrode; and

the first electrical circuit comprises:

an electrical connection between the first electrode of the first SBAR and the second electrode of the second SBAR, and

an electrical connection between the second electrode of the first SBAR and the first electrode of the second SBAR.

26. The transformer of claim 21, in which:

the first electrical circuit connects the one of the FBARs of the first SBAR in one of (a) parallel and (b) anti-series with the one of the FBARs of the second SBAR; and

the second electrical circuit connects the other of the FBARs of the first SBAR in one of (c) parallel and (d) anti-series with the other of the FBARs of the second SBAR.

27. The transformer of claim 26, in which:

the transformer additionally comprises first terminals and second terminals;

the first electrical circuit additionally connects the ones of the FBARs to the first terminals; and

the second electrical circuit additionally connects the others of the FBARs to the second terminals.

28. The transformer of claim 26, in which the first terminals constitute primary terminals and the second terminals constitute secondary terminals.

29. The transformer of claim 21, in which the acoustic decouplers each comprise a layer of acoustic decoupling material.

30. The transformer of claim 21, in which the acoustic decouplers each comprise a Bragg structure.